COMPUTER METHOD OF PLANE SURFACE DESIGN

General

Plane Surface Design (PSD) is a computer program, written in FORTRAN IV, to facilitate land leveling design. Land leveling or grading is the reshaping of the surface of the land to a planned grade. The program will:

1. Reduce topographic survey data (differential levels only). Previously reduced topographic data may be used instead of the raw data.
2. Fit a plane to the problem area ("best fit" or user defined).
3. Calculate the planimetric area and the volumes of cut and fill to construct the plane.
4. Print grid map of the field area suitable for use in construction.

Program Organization

The program is structured to permit considerable flexibility in the field survey operations, the sequence of input data, and the updating of input data for multiple designs. To provide this flexibility, the data is uniquely identified. The program uses control words for identification which are words, abbreviations, or acronyms related to and describing the data itself. Examples are C/F RATIO which identifies the cut/fill ratio, FS which identifies a foresight, etc. Each control word will be described in detail elsewhere.

The problem area is presented to the program in the form of a rectangular grid system supplemented by irregular fringe area as required to define the field to be leveled. The survey points are referenced to X and Y Cartesian coordinates to describe horizontal positions. Vertical data may be elevation or rod reading recorded directly from the field survey. The program will reduce rod readings, if used, to elevation. All internal computations and the output are referenced to elevation.

After all the data needed for the problem solution are read into the computer, the program will compute the slopes for the "best fit" plane using a linear regression technique. The elevation for slope, from Statistical Methods, George W. Snedecor, Fifth Edition, 1957, page 415, are:

$$S_X = \frac{\Sigma y^2 \Sigma xe - \Sigma xy \Sigma ye}{\Sigma x^2 \Sigma y^2 - (\Sigma xy)^2}$$

$$S_Y = \frac{\Sigma x^2 \Sigma ye - \Sigma xy \Sigma xe}{\Sigma x^2 \Sigma y^2 - (\Sigma xy)^2}$$

where S_X = slope in ft/ft in the x direction
S_Y = slope in ft/ft in the y direction

$$\Sigma x^2 = \Sigma(X_i - \overline{X})^2$$
$$\Sigma y^2 = \Sigma(Y_i - \overline{Y})^2$$
$$\Sigma xy = \Sigma(X_i - \overline{X})\ (Y_i - \overline{Y})$$
$$\Sigma xe = \Sigma(X_i - \overline{X})\ (E_i - \overline{E})$$
$$\Sigma ye = \Sigma(Y_i - \overline{Y})\ (E_i - \overline{E})$$

X_i, Y_i, E_i = location and elevation of centroid of each grid or fringe area and $\overline{X}$, $\overline{Y}$, $\overline{E}$ = location and elevation of centroid of the total field area.

In using this method the plane is fitted to the centroids of each grid or fringe area by the method of least squares which specifies that the sum of squares of vertical distances from plane to centroid shall be minimum. A plane surface so designed will require minimum earthwork to construct.

If the slopes so determined are within the predefined slope limits, the program will use the computed slopes; otherwise, the appropriate slope limit will be used.

The elevation of the plane is adjusted to balance the cut and fill volumes to the desired cut/fill ratio. In the event a maximum or minimum elevation has been set for a point location in the field the plane is rotated, if needed, to meet these elevation limits.

The earthwork volumes for each grid and fringe area are then computed and accumulated using the equations:

$$V_c = \frac{A\ H_c^2}{(27)(N)(H_c + H_f)}$$

$$V_f = \frac{A\ H_f^2}{(27)(N)(H_c + H_f)}$$

where V_c = volume of cut in cubic yards
V_f = volume of fill in cubic yards
A = area in square feet of grid or fringe area
H_c = sum of cuts of all stakes in the area
H_f = sum of fills of all stakes in the area
N = number of stakes in the area

These equations compute the earthwork volumes based on the average depth of cut and/or fill for the grid and/or fringe area. If both cut and fill occur in the same grid or fringe area, the volumes are adjusted according to the proportion of the cut or fill to the total depth of cut and fill for the area.

The average depth of cut and/or fill assumes that each stake represents 1/N'th of the grid or fringe area, i.e. H_c/N and H_f/N. Any deviation from this caused by the shape of the area or the distribution of stakes around the area can introduce an error, generally less than 1-2 percent, into the earthwork computations. Fringe areas are the only ones which can be irregularly shaped (grid areas are always rectangles); therefore, wherever possible, fringe areas should be convex polygons with the stakes more or less uniformly spaced around the perimeter.

The program will print out the basic information for the plane; the location and elevation of the centroid; and the slopes in both the x and y directions. Also printed are the cut/fill volumes, the cut/fill ratio, and the area of the field. If more detail is desired, a digital grid sheet can be printed showing the original and computed ground elevations and the depth of cut or fill for each grid point. The same elevation and depth information for each point that is not on a grid intersection, but is included for fringe areas, will be printed in a table.

Program Capabilities and Limitations

The program will accept a field of any size or shape that will fit within a 52 x 52 station grid rectangle. The grid row or line labels may be alpha (A, B, C,---Z, AA, BB, CC,---ZZ) or numeric (1, 2, 3,---51, 52). These are the only dimensional limitations imposed by the program logic. Additional limitations imposed by the computer configuration used are the field size, the number of fringe areas, and the number of fringe and/or odd points. For example, the version operational on the Regional Technical Service Center's IBM 1130 computer system has a maximum field size of 26 x 26 station grid. Additional limitations of the 1130 version are:

1. Maximum number of fringe areas = 20.

2. Maximum number of odd or fringe points = 100. An "odd" point is any point not on a grid intersection which may be later identified as a fringe point.

3. Maximum elevation = 3,276.7 feet.

Input

Input data are recorded in standard 80-column cards or card images. The user controls the program with control words at the beginning of each input record which consists of the control word and all of the data related to the control word. A record may contain data from one or more consecutive cards. The data must be in card columns 1 through 70. Columns 71-80 are reserved for user identification or sequence numbers and are not examined by the program.

The program loads and prints the input data one card at a time. The program then checks for errors in the control word and data. Errors, if present, are indicated by a printed message of the form:

ERROR n $

following the list of the card where n is an error message number (see PSD Error Messages) and the $ points to the last character analyzed by the program prior to detection of the error. Once an error is detected in the record, the remainder of that record is not checked. The program continues to read and edit the remaining cards of the job but will not execute the solution phase of the program if the error is severe enough to prevent a successful run.

It is impossible or impractical in some cases for the program to completely check every input data item for reasonableness. Data limits, where needed, are given in the detailed description for each control word.

The program recognizes several delimiters or symbols signifying the end or separation of data items. A provision has been made for the inclusion of comments or remarks in the input data itself. All information on a card following an asterisk (except for the job title records) is considered a comment. This permits thorough documentation of the problem and may be used to describe the design considerations. Generous use of this feature is recommended.

Many control words will accept more than one data item. The comma is used to separate the data items within the record. For example, the rod readings for a row of stakes may all be included in one record with a comma between each reading.

The equal sign signifies the end of the control word. All information following the equal sign up to the end of record is treated as data for the control word.

Right and left parentheses delineate certain special data that are described in detail in CONTROL WORDS.

The original input data to the program are survey data which may or may not be processed in some manner before being punched into cards which are read by the computer. Each time the data is transcribed from one medium to another a possible source of error exists, be it reading of numbers or arithmetic errors in reducing notes. It is desirable, therefore, to record the original survey data in a format that will enable the data to be punched directly from the survey notes. Grid sheets, if needed, may also be plotted from the same set of notes.

Figure 14-22.7 shows how a typical land leveling survey (Figure 14-22.8) might be recorded. All of the data required to design the job is

included in the survey notes. The set of notes can now be the one source of data for computer processing as well as any manual manipulation such as topographic maps, etc.

Care should be taken when recording the survey notes to make certain the notes are neat and legible. Mistaking one letter for a number or another letter is one obvious way errors can enter the data. A convention to reduce this type of error is:

1. Use all capital letters.
2. Slash the letter "O" as "Ø".
3. Use a block letter "I".
4. Slash the letter "Z" as "Ƶ".

Output

Basic output from the program are:

1. The listing of all input data (Figure 14-22.9).
2. Error messages as required.
3. Location and elevation of the centroid of the area (Figure 14-22.10).
4. Slopes in the x and y direction in percent (Figure 14-22.10).
5. Cut and fill volumes in cy (Figure 14-22.10).
6. Cut/fill ratio as a percent (Figure 14-22.10).
7. Planimetric area of the field in acres (Figure 14-22.10).

Additional detailed output if desired are:

8. Table of location, ground and grade elevations, and cut or fill of all fringe points not at a grid intersection (Figure 14-22.10).
9. A quasi-scaled diagram of all grid points observed giving the ground and grade elevations and cut or fill at each point (Figure 14-22.11).

Input Data Control Words

PLANE SURFACE DESIGN

This must be the first record of a job. This is an instruction to the program to initialize itself and prepare for a completely new job. This feature permits batching of jobs and insures that each job is independent of any other--that no values are carried over from one job to another and that all program assumed values are as described below.

TITLE = data

This control is used to load the job title records. Each record consists of columns 1-70 of a card and all data therein is maintained exactly as punched for labeling the top of each page of output. Up to two title records may be loaded. The second record may be replaced by loading a third, fourth, etc., title record. In each case, any title record loaded after the first two title records replaces and becomes the second title record. This feature may be used to vary the second line of the title for each pass within a job.

GRID = g_x, g_y

This control, if used, must precede all topographic data for a job. It is used to load the dimensions of the grid intervals--"g_x" is the X grid interval, "g_y" is the Y grid interval in feet. Unless this control is used the program assumes the grid intervals are 100 feet in both the X and Y directions. In some cases, the topography may be such that grid intervals need to be larger or smaller than 100 feet. In other cases, it may be advantageous to use an X-interval of one size and a Y-interval of some other size. The minimum-maximum values are 10 and 500 feet respectively for both the X and Y intervals.

ØRIGIN = $\{\begin{matrix}\text{UPPER}\\\text{LOWER}\end{matrix}\}$, $\{\begin{matrix}\text{LEFT}\\\text{RIGHT}\end{matrix}\}$

This control is used to cause the program to orient the output in the form most convenient for field use. The origin may be placed in the upper left, upper right, lower left, or lower right corner of the output sheets.

SLØPE (X) = S_{min}, S_{max}

SLØPE (Y) = S_{min}, S_{max}

The slope of the plane may be restrained in either or both the X and Y directions. S_{min} and S_{max} are the minimum and maximum permissible slopes in percent, not to exceed $\pm$10 percent. The slope sign convention

used in the program is: If elevation increases moving away from the origin, the sign is positive (+); if the elevation decreases, the sign is negative (-).

C/F RATIØ = data

This control specifies the design ratio of excavation to fill yardage. It is used to account for compaction and materials wasted during the construction operations. This control must be used at least once per job. The program goes through a trial and error procedure to adjust the elevation of the plane so that the computed ratio is within 3 percent of the required value.

BØRRØW = data

This control is used to define the volume of material in cubic yards to be brought into the leveled area from an outside source. It is added to the cut volumes for balancing the cut/fill ratio.

WASTE = data

This control is used to define the volume of material in cubic yards that is to be removed from the leveled area. This option will provide extra material for a ditch berm, fill a gully, etc., for which definite volumes are desired. WASTE is added to fill volumes for balancing the cut/fill ratio.

BM = data

This control indicates that the vertical topographic data are field survey data (rod readings) and loads the benchmark elevation.

BS = data

This control is used to load a backsight to the benchmark or a foresight to compute HI for the following topographic data.

FS = data

This control loads a foresight as the first step of moving the instrument during the field survey.

X+ (ℓ_x, ℓ_y) = data

X- (ℓ_x, ℓ_y) = data

Y+ (ℓ_x, ℓ_y) = data

Y- (ℓ_x, ℓ_y) = data

These controls are used to load topographic data that are predominantly in a straight line. The letter X or Y indicates the axis with which the line is parallel. The + indicates that the line goes away from the origin; the - indicates it goes toward the origin. ℓ_x and ℓ_y are the X and Y labels respectively of the grid point where the line begins.

The data following the = sign is of two types. The first type is the vertical data for grid points that lie on the designated line. It consists of the elevation or rod reading only. The second type, always bounded by parentheses, is the horizontal and vertical data for observations that do not lie on the designated line or in the straight forward sequences. They may include observations that will later be used to define fringe areas. The data within the parentheses consist of three pieces of information:

1. The X position of the point being observed. It is the X-grid label or the X-grid label plus or minus a distance.

2. The Y position of the point. It is the Y-grid label or the Y-grid label plus or minus a distance.

3. The elevation or rod reading of the point.

F (n) = data

This control is used to define irregular fringe areas. "n" is a number assigned by the user to identify the fringe area. No two fringe areas may have the same identification number. There must be at least three observations for each fringe area. All observations must be enclosed within parentheses and consist of the same data as parts 1 and 2 or 1, 2, and 3 of the parenthetical X-Y data described above. Parts 1 and 2 only are required to refer to a point that is observed somewhere else in the topographic data.

Grid labels in both the X and Y directions may be numbers or letters, but they must be consistent within a job. The first topographic record is analyzed to determine the convention being used and all succeeding uses must agree. If numeric labels are used, they start at 1 at the origin and increase by 1's up to the problem limit. When using alphabetic labels, the origin is A and goes up one letter at a time to the problem limit or Z. The next label following Z is AA, BB, etc., through ZZ or the problem limit.

All topographic records may be continued onto the following data cards if required. In this case, a continuation is indicated by ending the card with an unbounded comma. (An unbounded comma is one that is not enclosed within parentheses.) The observations are then continued on the following card just as if the first card had more than 70 usable

columns. The control word is not repeated. There is no limit on the number of continuation cards that may be used.

MAXELEV (x,y) = data
MINELEV (x,y) = data

These controls are used to set elevation limits at any point in the field. If the computed grade elevation of the point is outside the limits, i.e. greater than MAXELEV or less than MINELEV, the slopes of the plane are adjusted, up to the slope limits, to raise or lower the grade elevation at the point. If the slope limits are such that the plane cannot be rotated enough, the plane is raised or lowered to meet the limits and a warning is printed. This eliminates the cut/fill ratio balance. If the slope limits are such that both elevation limits cannot be met, the field is raised to the MINELEV, MAXELEV is ignored and a warning is printed.

GØ,DETAIL

This control tells the program that all data necessary for a run has been loaded and that computations are to begin. If an error has been detected, the command is ignored, a message is printed and the program continues reading input data until a "PLANE SURFACE DESIGN" card is read and a new job initialized or until the last data card is read which terminates the program. All the output items listed under "OUTPUT" are printed.

GØ

This control is identical to GØ,DETAIL except the quasi-scaled diagram of the grid points and the table of fringe area points are not printed.

END JOB

This is the last record of a job.

Order of Input

Although the program has a fairly flexible order of input, there is a definite sequence in which some of the control words can be used. For example, PLANE SURFACE DESIGN must be the first record in the job.

If the grid intervals in either direction are changed from the program assumed values, the new grid intervals (GRID) must be read before any topographic data are read.

The program recognizes the topographic data as rod readings if the height of instrument (HI) has been computed. This requires the bench-mark (BM) elevation and backsight (BS) be read in that order to compute

the HI prior to reading the topographic data. The same HI is used to reduce all the following topographic data unless a new HI is computed by reading a foresight (FS) to a turning point followed by a BS or by entering a new BM elevation followed by a BS.

The remaining control words may be used in any order and, except for the topographic and fringe data, may be added, deleted, or altered as desired for multiple solutions.

PSD Error Messages

1 Control card expected but not recognized.
2 Illegal benchmark elevation data.
3 Benchmark elevation has not been loaded.
4 Illegal backsight data.
5 Height of instrument has not been established.
6 Illegal foresight data.
7 Illegal maximum or minimum slope data or slope exceeds program limits.
8 Illegal grid size data.
9 Grid size too large (500) or too small (10).
10 Illegal cut/fill ratio data.
11 Illegal form of grid labels.
12 Number of fringe areas exceeds program limits.
13 Illegal fringe area number data.
14 Fringe area number has been used before.
15 X-label data is illegal or outside program limits.
16 Comma must follow X-label.
17 Y-label data is illegal or outside program limits.
18 Right parenthesis is expected.
19 Equal sign is expected.
20 All fringe area data must be within parentheses.
21 Data error within parentheses.
22 Data error for elevation or rod reading.
23 Point lies outside grid in X+ direction--program limits have been exceeded.
24 Point lies outside grid in X- direction--data error.
25 Point lies outside grid in Y+ direction--program limits have been exceeded.
26 Point lies outside grid in Y- direction--data error.
27 Grid point has been observed before; this observation used--Warning Only.
28 Number of fringe area points exceeds program limits.
29 Number of "odd" points exceeds program limit. An odd point is one observed in X/Y data but not on the line being run.
30 The last record ended with a comma so a continuation is expected but a control card has been recognized.
31 Grid size loaded more than once or after topographic data has been loaded.
32 Illegal data for "BØRRØW=" or "WASTE=" control words.
33 Illegal data for "MAXELEV=" or "MINELEV=" control words.
34 Illegal data for "ØRIGIN=" control word--Warning Only, program assumes UPPER LEFT.

Note: Illegal data are data that cannot be recognized because of duplicate decimal, alpha character when numeric expected or numeric character when alpha expected, etc.

T E. Eye #1
Ø M. Wright 2-20-70

~~Sta~~ ~~B.S.~~ ~~H.I.~~ ~~F.S. or Grade Rod~~ ~~Elev. or Planned Elev.~~

PLANE SURFACE DESIGN
Title = IMA Smoothin,
Title = Field 4B
*
BM = 48.8 * Nail in Gatepost at N.E. Corner of Field 4B
BS = 1.00 * Instrument at grid point (A,4)
*

X+(A,1)=	1.5,	1.2,	1.0,	0.8,	1.1,	3.3, 4.3, 4.2, 2.3
X-(I,2)=	4.0,	6.2,	6.5,	6.5,	6.2,	5.5, 5.7, 5.1, 4.2
X+(A,3)=	3.8,	5.5,	6.9,	7.5,	7.6,	7.5, 7.1, 5.7, 3.3
X-(I,4)=	4.4,	4.8,	6.9,	8.2,	8.5,	8.5, 7.6, 6.0, 4.4
X+(A,5)=	6.3,	7.5,	9.1,	9.3,	9.2,	8.7, 6.3, 6.8, 6.8
X-(I,6)=	8.6,	8.0,	8.1,	8.8,	10.1,	10.2, 10.0, 8.6, 7.2

*
FS = 7.52 * Top of (A,4) Stake
BS = 1.51 * Instrument at (0,9)
*

X+(A,7)=	3.2,	3.7,	4.6,	4.8,	4.7,	3.2, 3.5, 4.1, 4.4
X-(I,8)=	6.0,	5.7,	5.4,	5.0,	5.2,	5.3, 5.2, 4.5, 2.0
F(1) =	(B,8),	(B,9),	(A,8+60,0.8),		(A,8)	
X+(B,9)=	2.6,	5.4,	(C,9+40,4.8),		5.8,	5.9, 5.9, 6.3, 6.3, 6.6
X-(I,10)=	7.4,	6.6,	6.6,	6.3,	6.0,	(D,9+80, 5.3), (E,10+20, 6.0)
X+(G,11)=	(F,10+60, 6.3),		6.9,	(G,11+30, 6.9),		7.0, 7.3

~~Sta~~ ~~B.S.~~ ~~H.I.~~ ~~F.S. or Grade Rod~~ ~~Elev. or Planned Elev.~~ #2

F(2) =	(I,11), (I,12, 7.7), (I, 12+30, 7.7), (G,11), (H,11)	(H,11+80, 6.8), (G,11+30),
F(3) =	(G,11+30), (F,10+60), (E,10+20),	(E,10), (F,10), (G,10), (G,11)
F(4) =	(E,10+20), (D,9+80), (C,9+40),	(B,9), (C,9), (D,9), (E,9), (E,10)

*
* Design Requirements
*
C/F Ratio = 1.55 * Based on work on field 5 last year.
Slope (X) = 0,0 * Flat in X direction
Slope (Y) = -1.0, -0.7 * 0.7 to 1.0 percent Slope to South.
Go, Detail

Figure 14-22.7 Notes - plane surface design

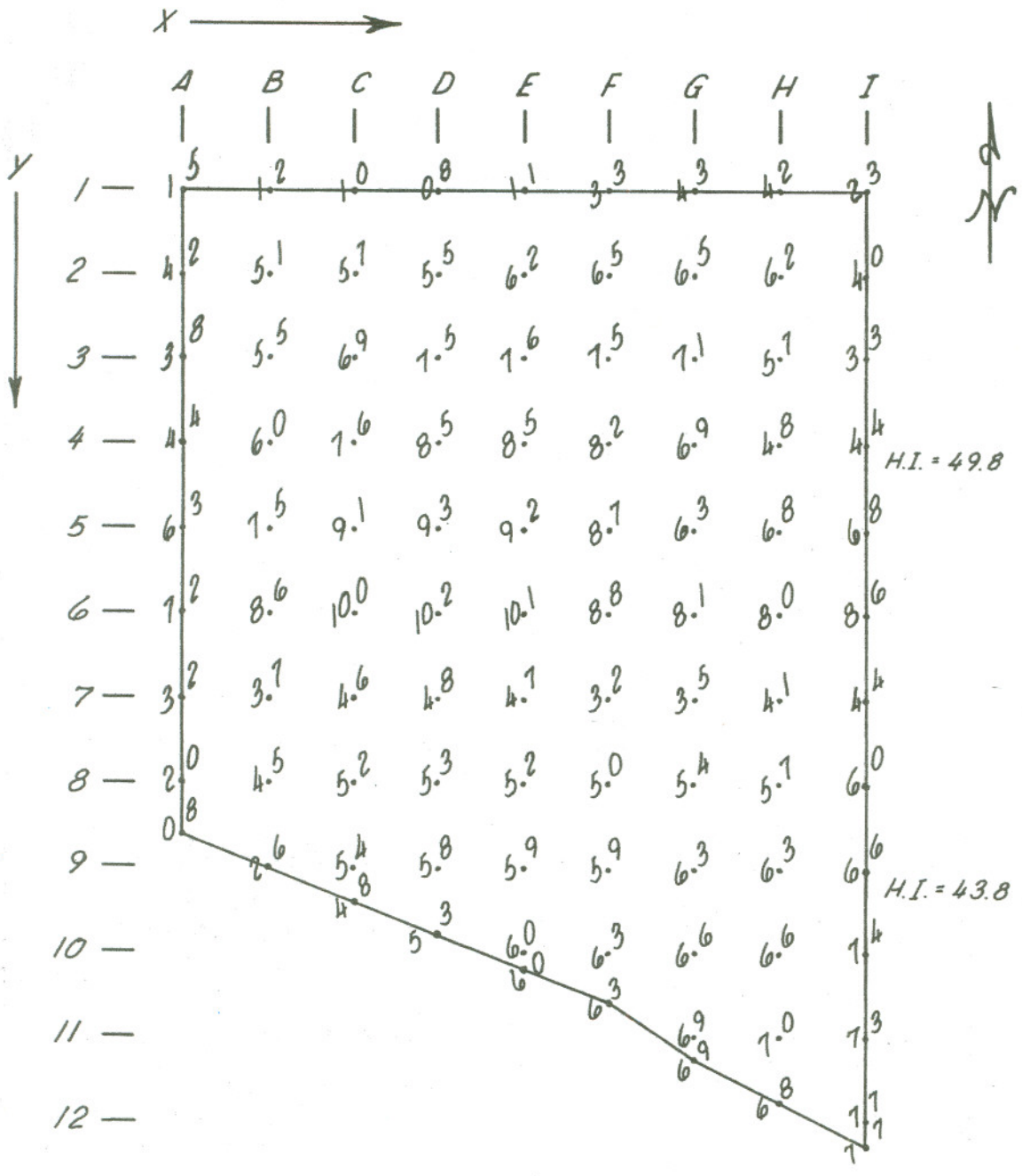

Figure 14-22.8 Grid layout

```
PSD XEQ    T+-E
    REV 01/29/69

                    80-80 LIST OF INPUT DATA
PLANE SURFACE DESIGN
TITLE= IMA SMOOTHIN,       IRRIGATION CITY, ROUGHCO.,ANYSTATE.
TITLE= FIELD 4B
*
BM= 48.8 *NAIL IN GATEPOST AT N.E. CORNER OF FIELD 4B
BS= 1.00 *INSTRUMENT AT GRID PCINT (A,4)
*
X+(A,1)= 1.5,1.2,1.0,0.8,1.1,3.3,4.3,4.2,2.3
X-(I,2)= 4.0,6.2,6.5,6.5,6.2,5.5,5.7,5.1,4.2
X+(A,3)= 3.8,5.5,6.9,7.5,7.6,7.5,7.1,5.7,3.3
X-(I,4)= 4.4,4.8,6.9,8.2,8.5,8.5,7.6,6.0,4.4
X+(A,5)= 6.3,7.5,9.1,9.3,9.2,8.7,6.3,6.8,6.8
X-(I,6)= 8.6,8.0,8.1,8.8,10.1,10.2,10.0,8.6,7.2
*
FS= 7.52* TOP OF (A,6) STAKE
BS= 1.51* INSTRUMENT AT(D,9)
*
X+(A,7)= 3.2,3.7,4.6,4.8,4.7,3.2,3.5,4.1,4.4
X-(I,8)= 6.0,5.7,5.4,5.0,5.2,5.3,5.2,4.5,2.C
F(1)= (B,8),(B,9),(A,8+60,0.8),(A,8)
X+(B,9)= 2.6,5.4,(C,9+40,4.8),5.8,5.9,5.9,6.3,6.3,6.6
X-(I,10)= 7.4,6.6,6.6,6.3,6.0,(D,9+80,5.3),(E,10+20,6.0)
X+(G,11)= (F,10+60,6.3),6.9,(G,11+30,6.9),7.0,7.3
F(2)=(I,11),(I,12,7.7),(I,12+30,7.7),(H,11+80,6.8),(G,11+30),
     (G,11),(H,11)
F(3)= (G,11+30),(F,10+60),(E,10+20),(E,10),(F,10),(G,10),(G,11)
F(4)= (E,10+20),(D,9+80),(C,9+40),(B,9),(C,9),(D,9),(E,9),(E,10)
*
*        DESIGN REQUIREMENTS
*
C/F RATIO=1.55 * BASED ON WORK ON FIELD 5 LAST YEAR.
SLOPE(X)=0,0 * FLAT IN X-DIRECTION
SLOPE(Y)=-1.0,-0.7 * 0.7 TO 1.0 PERCENT SLOPE TO SOUTH
GO,DETAIL
```


Figure 14-22.9 Input data listing

```
PSD XEQ
    REV 01/29/69

                IMA SMOOTHIN,      IRRIGATION CITY, ROUGHCO.,ANYSTATE.
                FIELD 4B

PLANE SURFACE CENTROID ELEV.=    41.01
              X-Y COORDINATES= 526.53,  572.13
              SLOPES (X,Y)=  0.0000, -0.9171

              CUT  VOL=13884.6 CY                FIELD AREA=  17.11 AC
              FILL VOL= 9002.7 CY                C/F RATIO= 1.54


FRINGE POINTS NOT ON GRID COORDINATES.
X,Y COORDINATES          ELEV     GRADE      C/F

  A+00 ,  8+60           43.0      38.4      C 4.6
  I+00 , 12+30           36.1      35.0      C 1.1
  H+00 , 11+80           37.0      35.4      C 1.5
  G+00 , 11+30           36.9      35.9      C 1.0
  F+00 , 10+60           37.5      36.5      C 0.9
  E+00 , 10+20           37.8      36.9      C 0.9
  D+00 ,  9+80           38.5      37.3      C 1.2
  C+00 ,  9+40           39.0      37.6      C 1.3
```


Figure 14-22.10 Output design data

PSD XEQ
REV 01/29/69

IMA SMOOTHIN, IRRIGATION CITY, ROUGHCO.,ANYSTATE. PANEL 1/ 1
FIELD 4B

	A	B	C	D	E	F	G	H	I	
	48.3	48.6	48.8	49.0	48.7	46.5	45.5	45.6	47.5	
1	45.3	45.3	45.3	45.3	45.3	45.3	45.3	45.3	45.3	1
	C 3.0	C 3.3	C 3.5	C 3.7	C 3.4	C 1.2	C 0.2	C 0.3	C 2.2	
	45.6	44.7	44.1	44.3	43.6	43.3	43.3	43.6	45.8	
2	44.4	44.4	44.4	44.4	44.4	44.4	44.4	44.4	44.4	2
	C 1.2	C 0.3	F 0.3	F 0.1	F 0.8	F 1.1	F 1.1	F 0.8	C 1.4	
	46.0	44.3	42.9	42.3	42.2	42.3	42.7	44.1	46.5	
3	43.5	43.5	43.5	43.5	43.5	43.5	43.5	43.5	43.5	3
	C 2.5	C 0.8	F 0.6	F 1.2	F 1.3	F 1.2	F 0.8	C 0.6	C 3.0	
	45.4	43.8	42.2	41.3	41.3	41.6	42.9	45.0	45.4	
4	42.6	42.6	42.6	42.6	42.6	42.6	42.6	42.6	42.6	4
	C 2.8	C 1.2	F 0.4	F 1.3	F 1.3	F 1.0	C 0.3	C 2.4	C 2.8	
	43.5	42.3	40.7	40.5	40.6	41.1	43.5	43.0	43.0	
5	41.7	41.7	41.7	41.7	41.7	41.7	41.7	41.7	41.7	5
	C 1.8	C 0.6	F 1.0	F 1.2	F 1.1	F 0.6	C 1.8	C 1.3	C 1.3	
	42.6	41.2	39.8	39.6	39.7	41.0	41.7	41.8	41.2	
6	40.8	40.8	40.8	40.8	40.8	40.8	40.8	40.8	40.8	6
	C 1.8	C 0.4	F 1.0	F 1.2	F 1.1	C 0.2	C 0.9	C 1.0	C 0.4	
	40.6	40.1	39.2	39.0	39.1	40.6	40.3	39.7	39.4	
7	39.8	39.8	39.8	39.8	39.8	39.8	39.8	39.8	39.8	7
	C 0.7	C 0.2	F 0.7	F 0.9	F 0.8	C 0.7	C 0.4	F 0.2	F 0.5	
	41.8	39.3	38.6	38.5	38.6	38.8	38.4	38.1	37.8	
8	38.9	38.9	38.9	38.9	38.9	38.9	38.9	38.9	38.9	8
	C 2.9	C 0.4	F 0.3	F 0.4	F 0.3	F 0.1	F 0.5	F 0.8	F 1.1	
		41.2	38.4	38.0	37.9	37.9	37.5	37.5	37.2	
9		38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	9
		C 3.2	C 0.4	F 0.0	F 0.1	F 0.1	F 0.5	F 0.5	F 0.8	

Figure 14-22.11 Quasi-scaled diagram - ground, grade elevation and cut
(sheet 1 of 2)

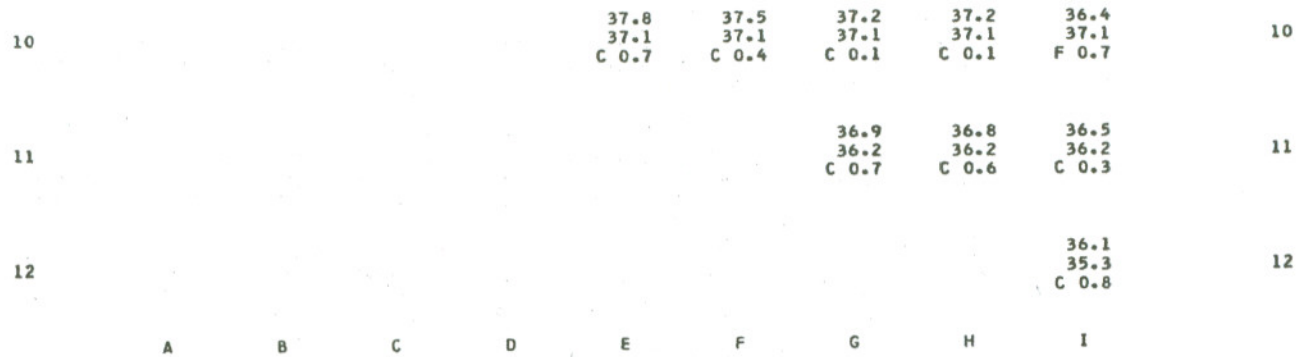

Figure 14-22.11 Quasi-scaled diagram - ground, grade elevation and cut (sheet 2 of 2)

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